Interactions of pions in the Si-W ECAL prototype

Towards a paper

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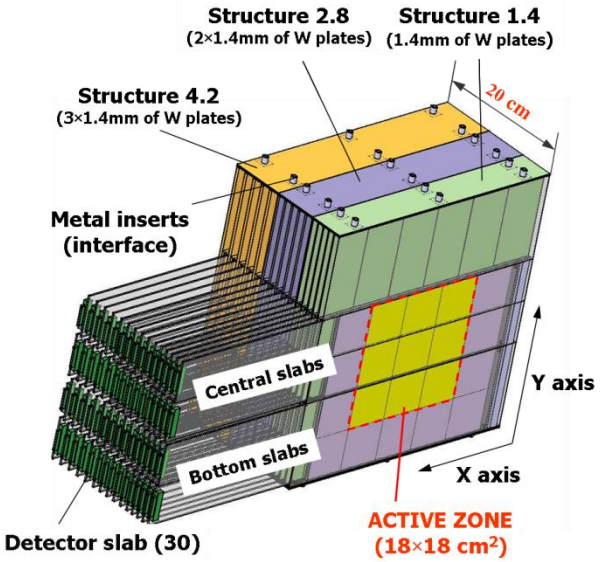
Introduction

- CALICE Analysis Note CAN-025:
  Study the interactions of π^- in the Si-W ECAL at low energies (2 – 10 GeV) and compare various Monte Carlo Models (physics lists) to this data
- The analysis has been revised and the manuscript for a publication has been submitted to the editorial board

Analysis setup

- Event sample:
  - Si-W ECAL physics prototype
  - 2008 FNAL test beam of π^- at 2, 4, 6, 8 and 10 GeV
  - Matching Monte Carlo (physics lists: FTFP_BERT, QGSP_BERT, LHEP, CHIPS, FTF_BIC, QGSP_BIC, QGS_BIC)
- Event cuts:
  - correct trigger, minimum number of hits (25), hits in correct region of ECAL (centre), minimum hit energy (0.6 mip), no noisy layers, muon rejection, electron rejection (based on found interaction layer > 6), multiple particle event rejection
- Sample size:
  - 500 k MC events (accepted 25 k – 300 k)
  - 150 k – 700 k data events (accepted 20 k – 450 k)



Event Classification

- Classify events as interacting or non-interacting
  - The absolute and relative energy increase in subsequent layers defines the interaction point
- In the note each category was again subdivided, but these categories depended too strongly on the cuts and will not be applied for the paper
- We will refine the event classification with machine learning techniques (more independent criteria) in future

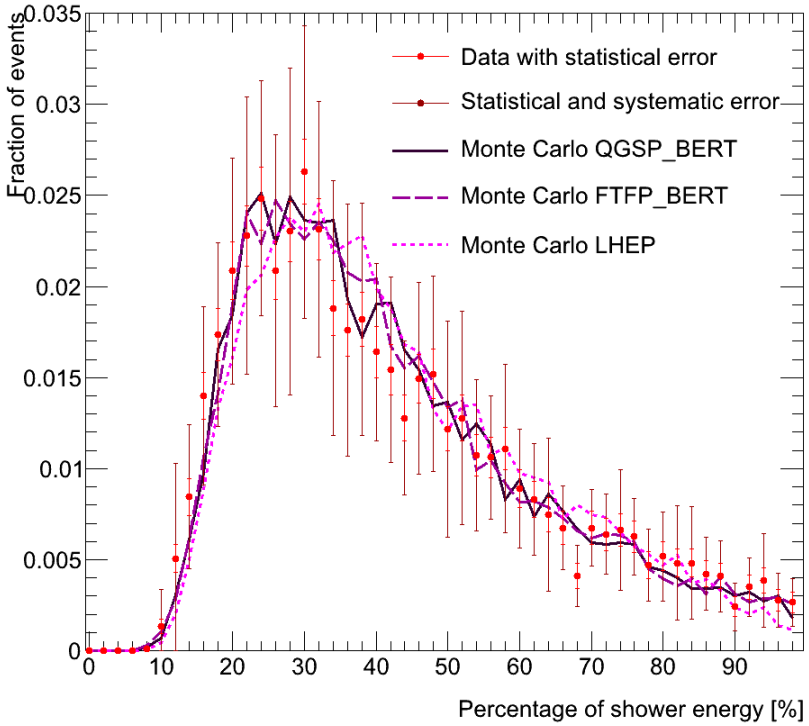
Event Classification (2)

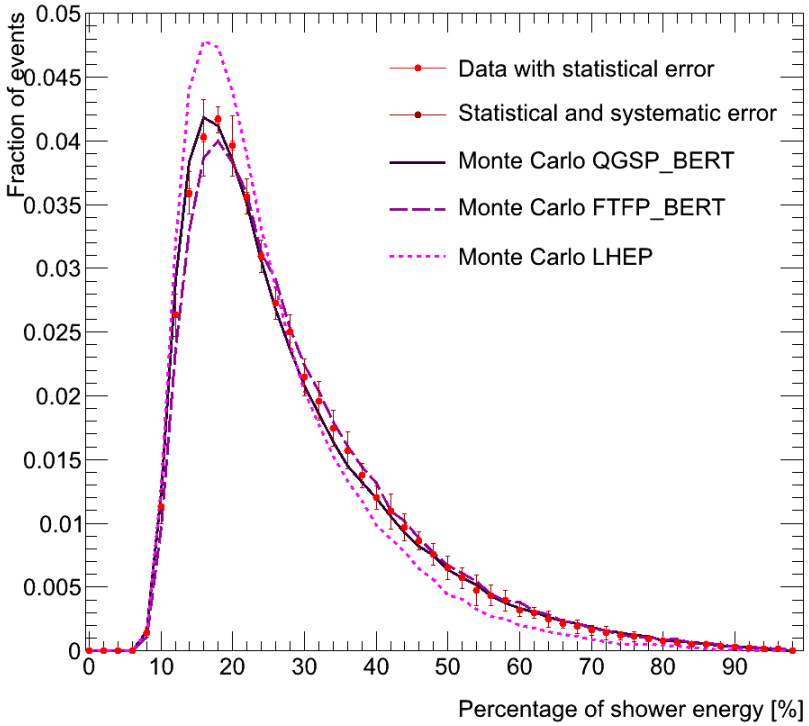
- Interactions are found based on two criteria:
  - Absolute energy increase
  - Relative energy increase
- Especially at low beam energies the second criterion is very important

E (GeV)	Fraction found by absolute energy criterion	Additional fraction found by relative energy criterion
2	0.34	0.28
4	0.61	o.18
6	0.72	0.13
8	0.78	0.10
10	0.83	0.08

High energy fraction in a single layer

The relative energy increase criterion selects also events with a strong local energy increase. These kind of events are not negligible at low beam energy.





At 2 GeV 20.3% (MC: 17 – 21.5%) of events have more than 60% of the energy deposited in a single layer. At 10 GeV this is 4.4% (MC: 2.3 – 6.4%).

Interaction layer

- The efficiency to find the interaction close to the real interaction layer:
  within one layer η(±1),
  within 2 layers η(±2)
- Model QGSP_BERT
  (other models give higher efficiencies)

E (GeV)	η(±1)	η(±2)
2	0.46	0.49
4	0.61	0.65
6	0.68	0.71
8	0.72	0.75
10	0.76	0.79

Interaction finding efficiency

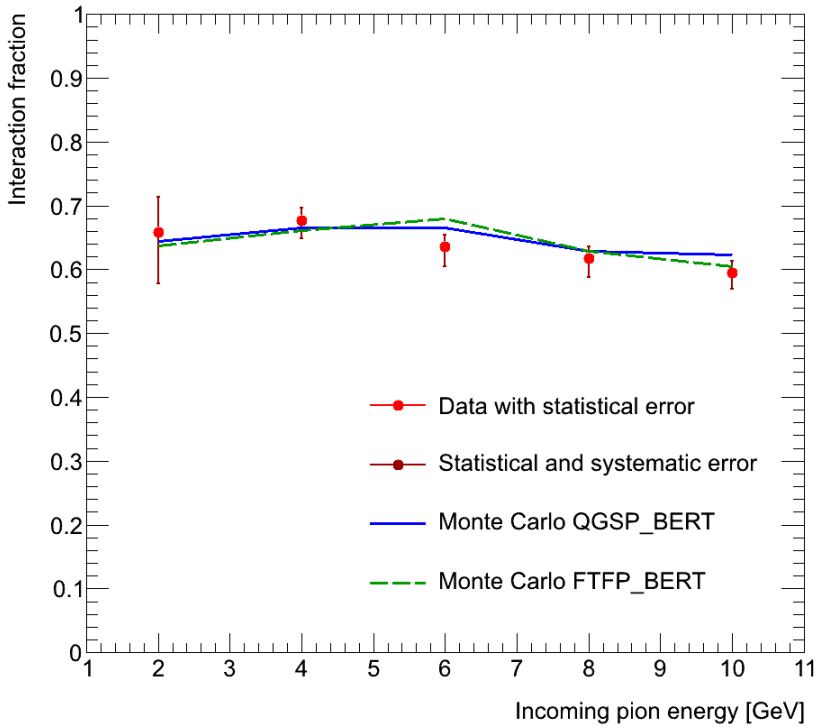
The fraction of all true interacting events that is classified as interacting
It depends on the MC physics list, especially at low energy,
the Bertini/Fritiof based models have the lowest efficiency

Physics list	2 GeV	4 GeV	6 GeV	8 GeV	10 GeV
QGSP_BERT	0.62	0.79	0.85	0.88	0.91
FTFP_BERT	0.63	0.79	0.89	0.92	0.94
FTF_BIC	0.66	0.77	0.86	0.90	0.93
LHEP	0.77	0.89	0.94	0.96	0.96
CHIPS	0.76	0.89	0.94	0.96	0.96
QGSP_BIC	0.75	0.88	0.93	0.96	0.96
QGS_BIC	0.75	0.88	0.93	0.96	0.96

Contamination = fraction of all events classified as interacting that is non-interacting, it is between 0.03 at 2 GeV and 0.05 at 10 GeV

Interaction fraction

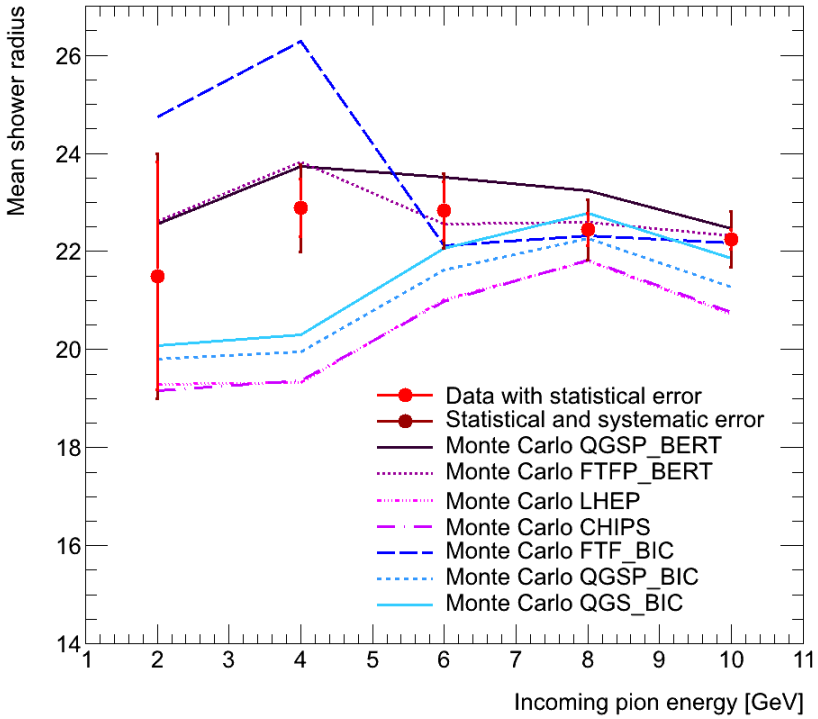
- The fraction of interacting events corrected with the interaction finding efficiency
- For data the average of the efficiencies of QGSP_BERT and FTFP_BERT is used
- Systematic error:
  - Electrons and muons,
  - multi-particle events,
  - non-interacting events,
  - variation in selection variables,
  - unknown efficiency
- The interaction fraction is consistent with the ECAL material budget and approximately independent of energy



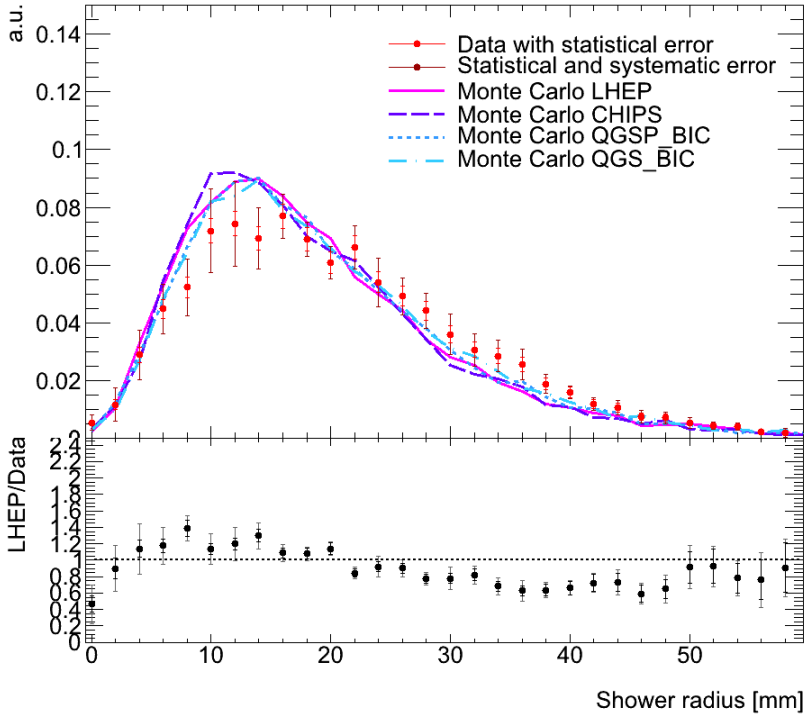
Mean shower radius (1)

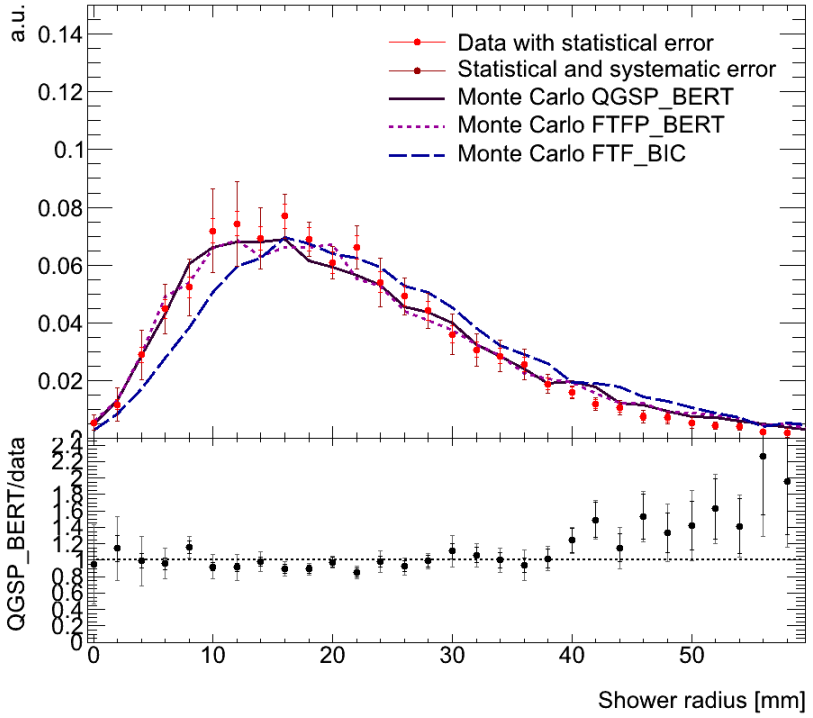
$$< r >_E = \sqrt{\sigma^2_{E,x} + \sigma^2_{E,y}}$$

- Clear division between MC models
- Bertini based models describe the data best

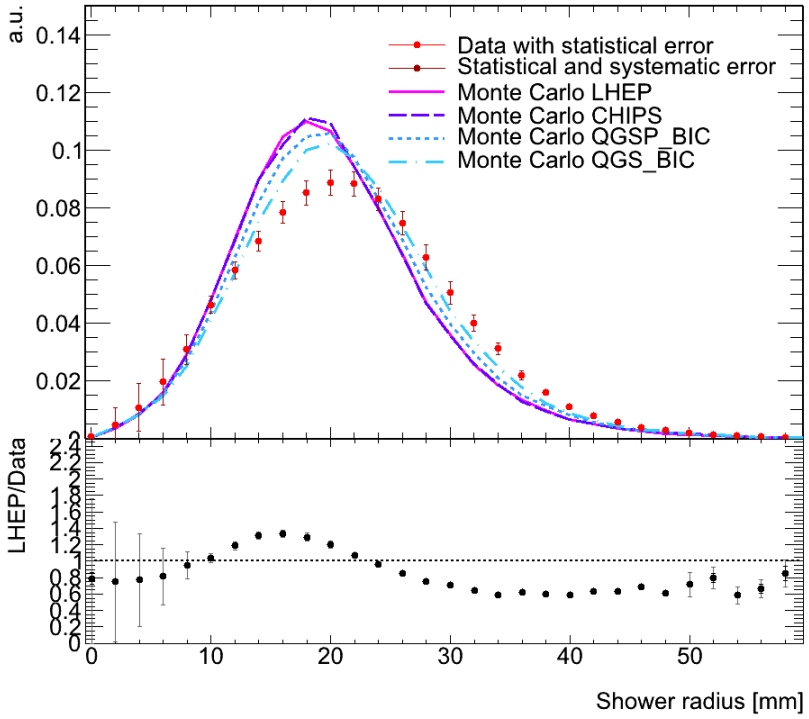


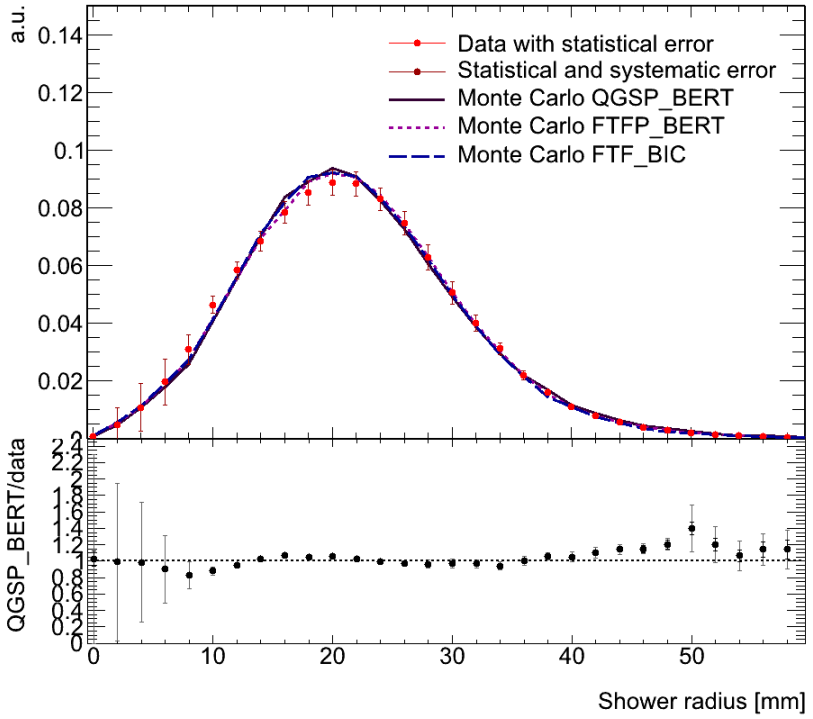
Mean shower radius (2)
2 GeV



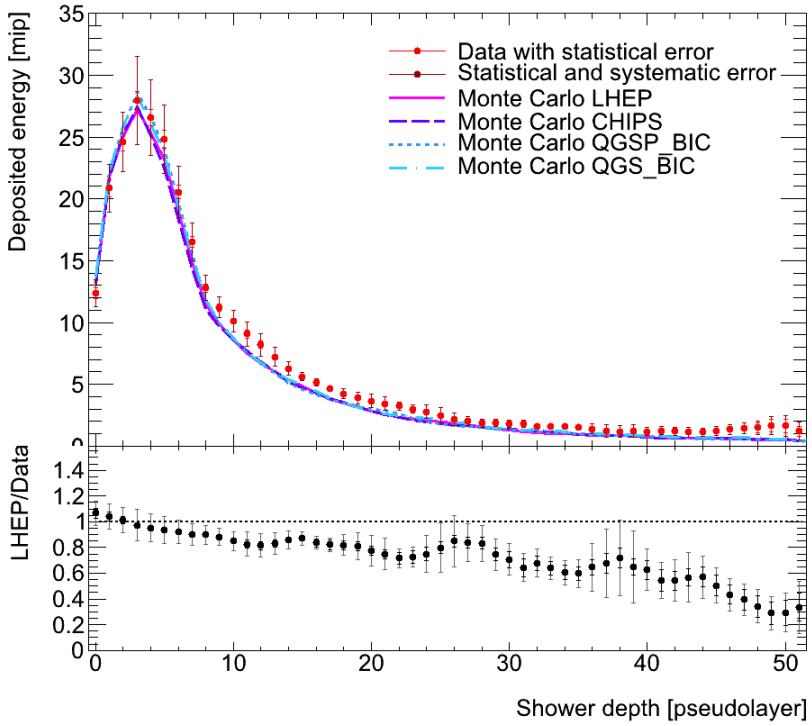


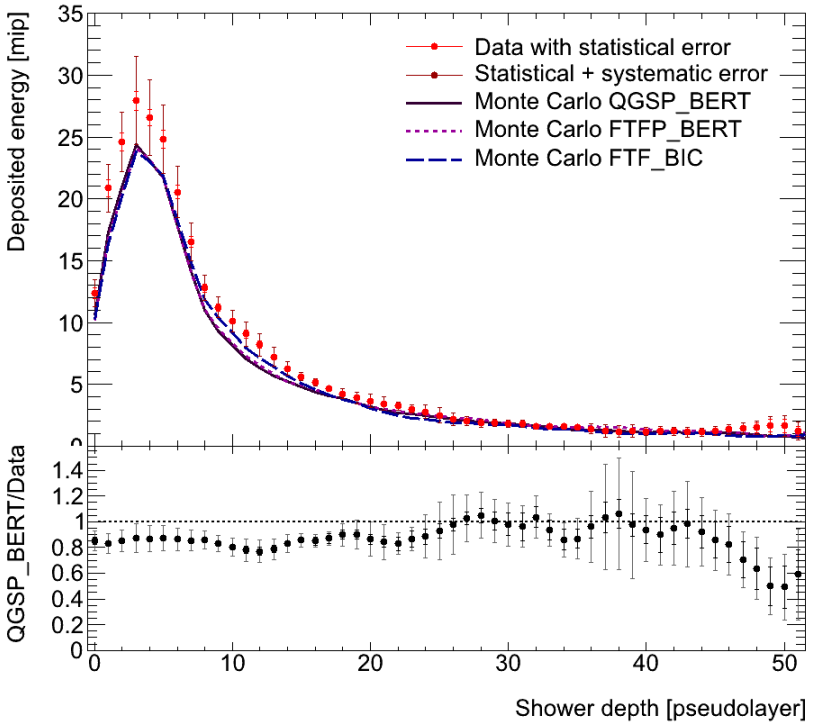
Mean shower radius (3)
10 GeV



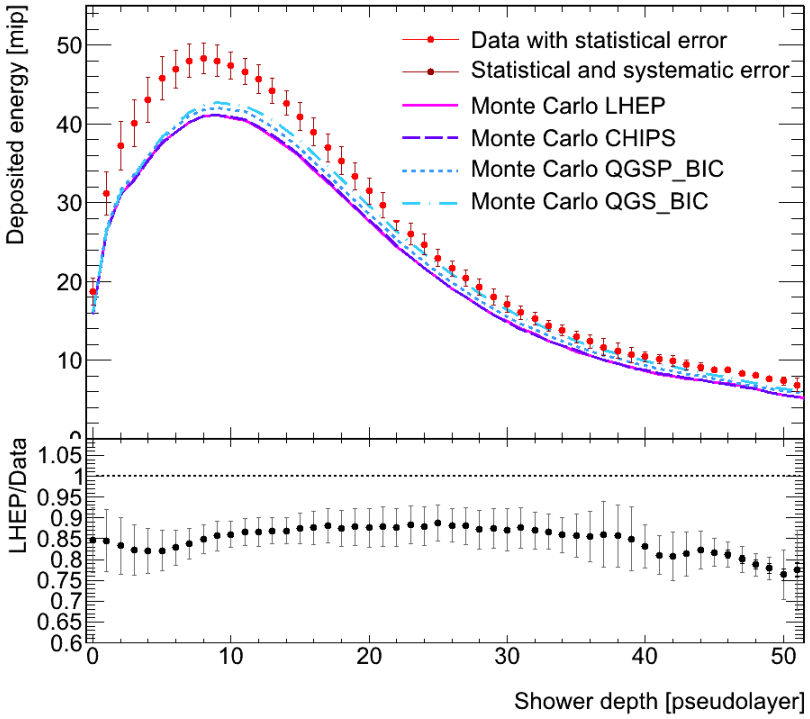


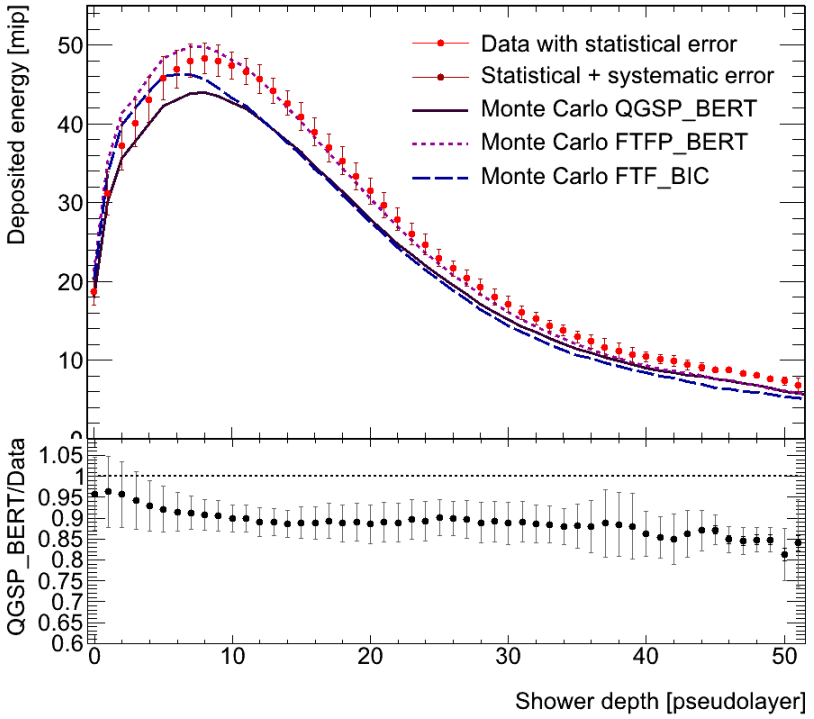
Longitudinal energy profile (1)
2 GeV





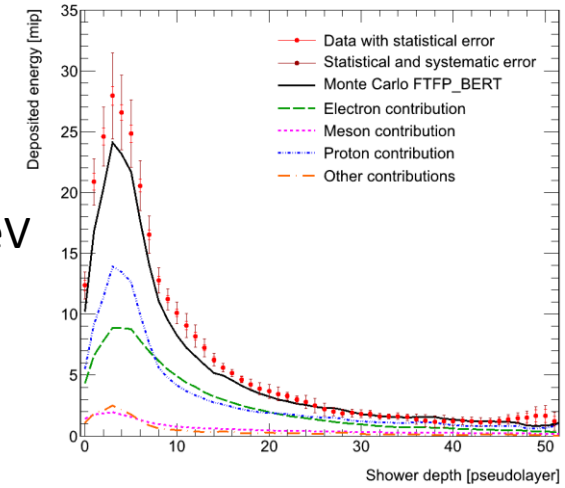
Longitudinal energy profile (2)
10 GeV

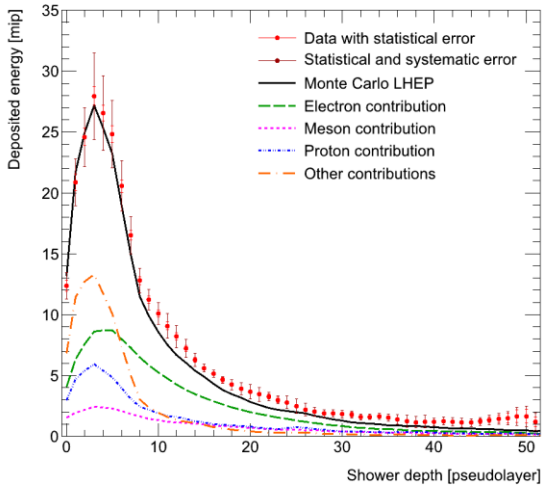




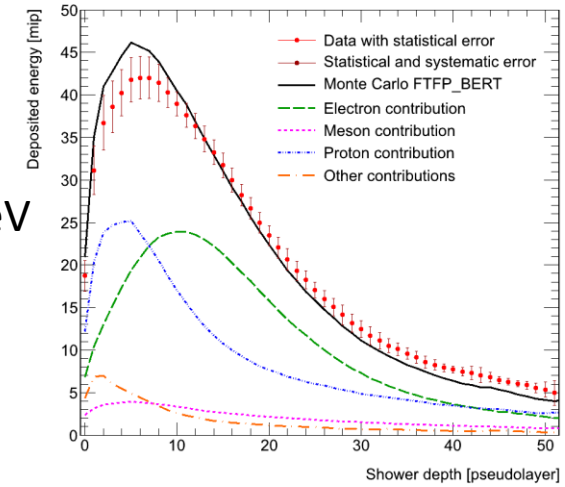
Longitudinal energy profile (3)

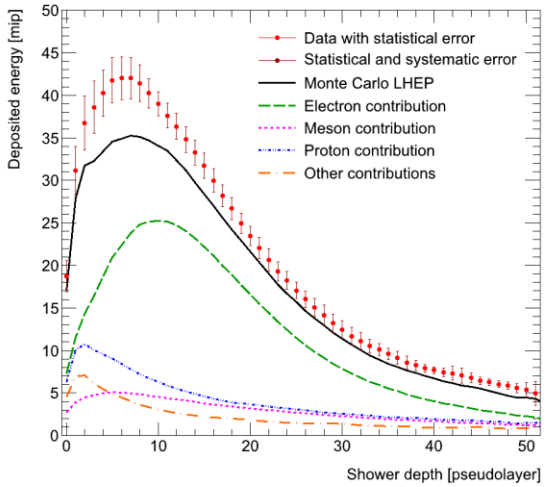
2 GeV





8 GeV





Summary

- Testbeams of pions at 2, 4, 6, 8 and 10 GeV were studied with the Si-W ECAL prototype
- Interacting events were identified using two criteria; absolute energy and relative energy increase
- The second is important especially at low beam energies
- Data and MC were compared in the interaction fraction, shower radius and longitudinal energy profile
- Bertini based models describe the data best

Selection criteria (backup)

- Interacting (inelastic hadronic interaction)
  - Absolute energy increase

    $E_i > E_{cut}$ && $E_{i+1} > E_{cut}$ && $E_{i+2} > E_{cut}$
  - Relative energy increase

    $F=(E_i+E_{i+1})/(E_{i-1}+E_{i-2}) > F_{cut}$ &&

    $F' = (E_{i+1}+E_{i+2})/(E_{i-1}+E_{i-2}) > F_{cut}$ &&

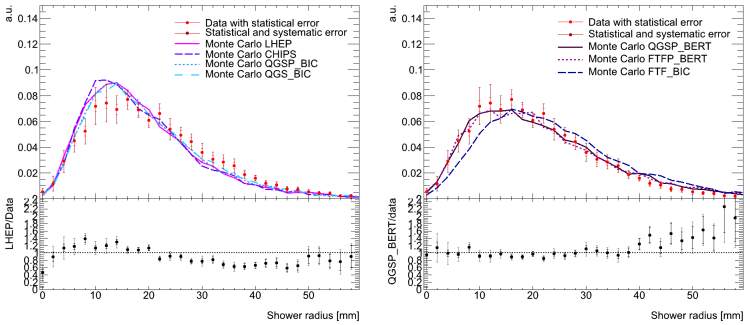
    $E_{aroundi} > 0.5E_i$

Contaminations (backup)

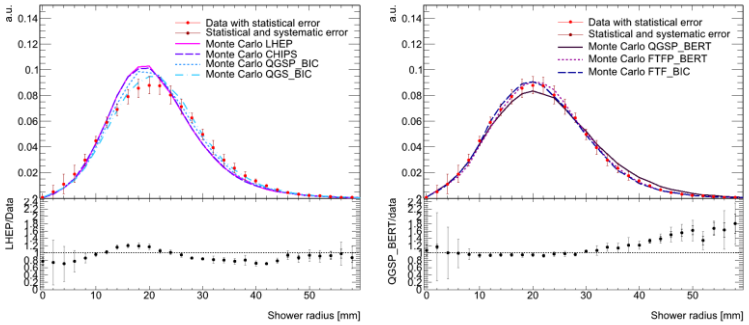
- Muons: 2% - 1% (2 GeV – 10 GeV)
- Multi-particle events: 13% - 2%
- Electrons: 3% - 0%
- Non-interacting events: 3% - 5%

Mean shower radius (backup)

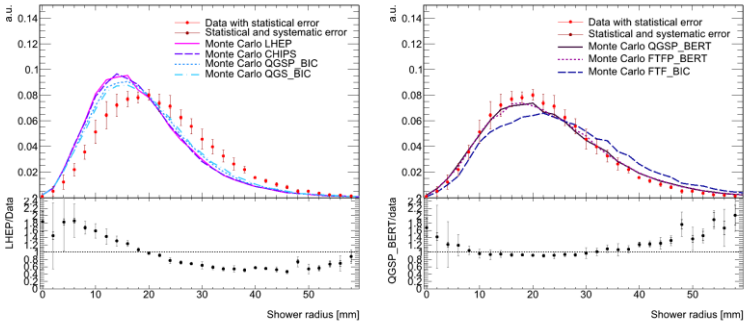
2 GeV



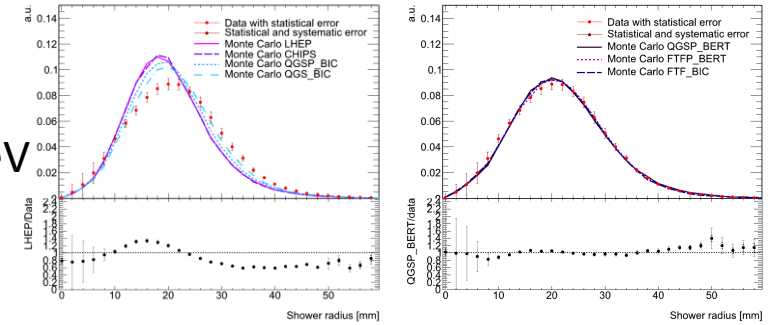
8 GeV



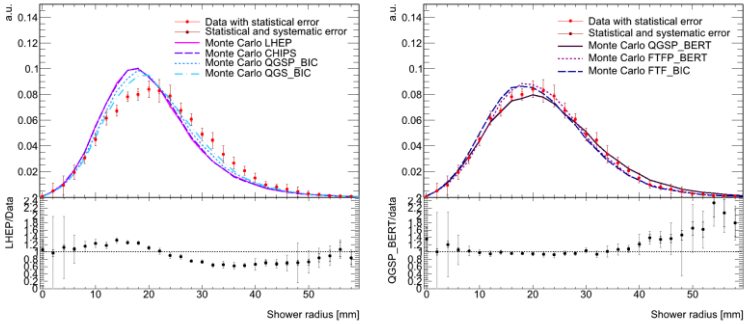
4 GeV



10 GeV

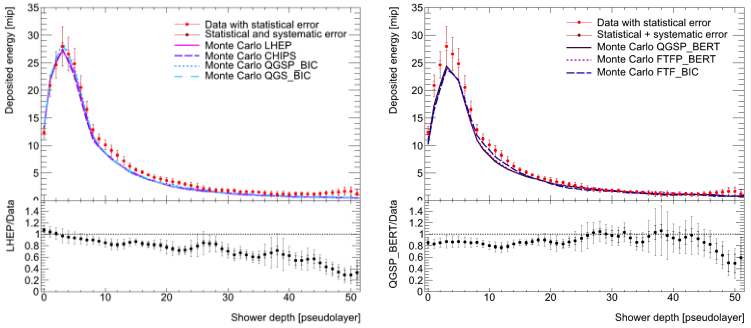


6 GeV

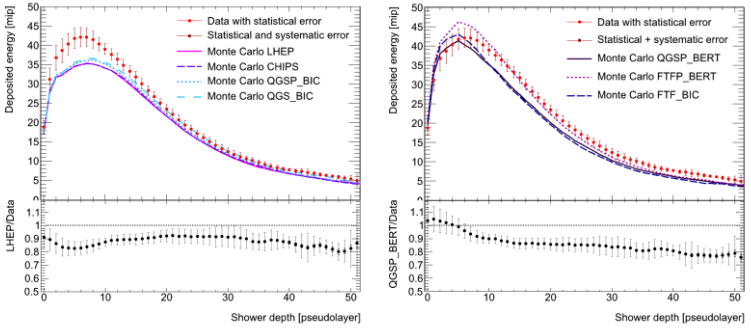


Longitudinal energy profile (backup)

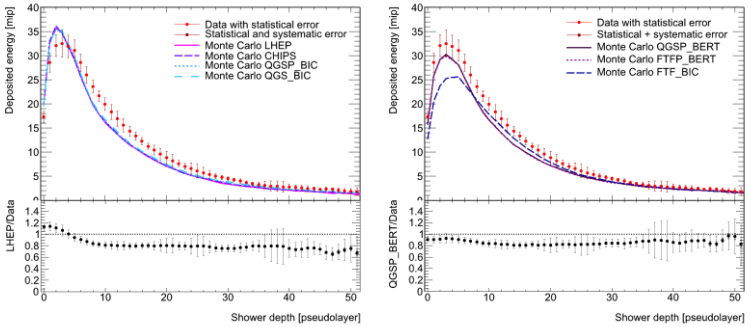
2 GeV



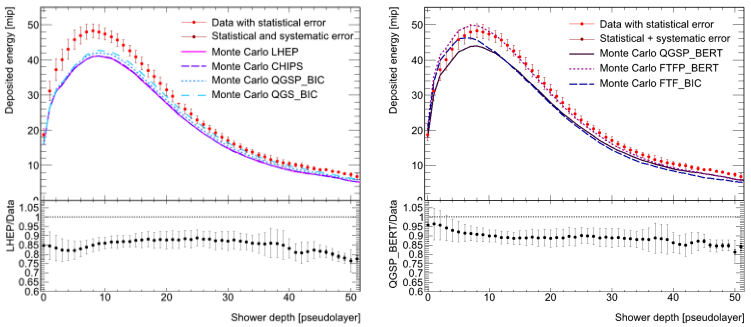
8 GeV



4 GeV



10 GeV



6 GeV